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§26. Surface Wave Structure of Vertical Liquid Film Flow with Artificial Oscillation

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In order to produce the electricity from a inertia confinement fusion reactor, it is necessary to protect the wall of the reactor chamber from high heat flux and high energy particles. One of the possible ideas for the chamber wall protection scheme is a liquid wall concept. The authors have been developing the direct numerical procedure so-called MARS (Multi-interface Advection and Reconstruction Solver) method [1] for tracking the free-surface behavior and studying the active control of the falling film flow along the vertical wall [2]. In this study, the MARS simulation has been carried out for investigating the surface wave structure of vertical liquid film flow with artificial oscillation.

NUMERICAL PROCEDURES

The governing equations are the continuity equation for multi-phase flows, momentum equation based on a one-field model and the energy equations:

$$\frac{\partial F_m}{\partial t} + \nabla(F_m V) - F_m \nabla V = 0 \tag{1}$$

$$\frac{\partial V}{\partial t} + \nabla(VV) = G - \frac{1}{\langle \rho \rangle}(\nabla P + \nabla \tau - F_V) \tag{2}$$

$$\frac{\partial V}{\partial t}\langle \rho C_V \rangle_M T + \nabla \langle \rho C_V \rangle_M TV = \nabla \langle \lambda \rangle_M \nabla T + Q \tag{3}$$

here, F is the volume fraction of fluid and the suffix m denotes the m-th fluid or phase, < > denotes a material average and F_V is a body force due to a surface tension based on the CSF (Continuum Surface Force) model[3]. τ shows a viscous shear stress. ρ is the density, λ is the thermal conductivity and C_v is the specific heat at constant volume. The surface volume-tracking technique is based on the MARS.

Figure 1 shows the computational domain and Table 1 shows the fluid properties used in this study. δ_0 is the equilibrium film thickness. The mesh sizes are used as (Δx, Δy)=(0.4δ_0, 0.1δ_0). Here, δ_0 is an equilibrium liquid film thickness derived by the Nusselt theory. The inlet mean velocity, U_0 derived by the Nusselt theory can be controlled with an external forcing as expressed:

$$U = [1 + \varepsilon \sin(2\pi f t)]U_0 \tag{4}$$

controlled with an external forcing as expressed:here, the forcing frequencies: f=20Hz, 30Hz and 45Hz are considered in the present study.

Figure 2 shows the surface wave structures. There are three groups of wave pattern such as (a) Solitary-shaped wave, (b) large solitary wave with several capillary waves and (c) solitary wave merged with capillary wave.

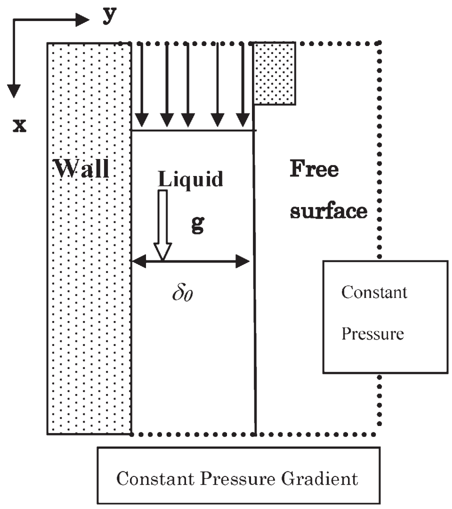

Fig. 1. Computational domain

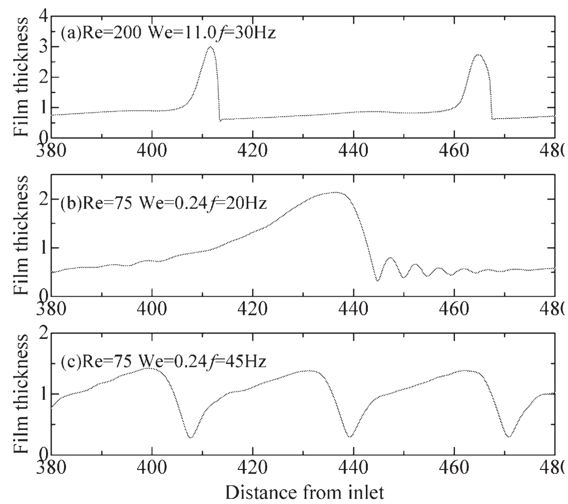

Fig. 2. Wave structure

In order to investigate the flow condition of the wave patterns, we introduce a new non-dimensional parameter, We/Ka (Kapitza number Ka=$\sigma\rho^{1/3}/g^{1/3}\mu^{4/3}$) The wave pattern can be classified based on We/Ka as shown in Fig. 3.

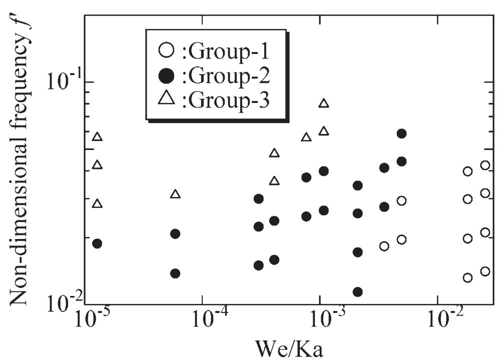

Fig. 3 Wave pattern mapping

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